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## **ABSTRACT**

This report describes the technical progress made on the Pittsburgh Air Quality Study (PAQS) during the period of February through July of 2002. The major activity during this project period was the continuation of the ambient monitoring effort. Work was also initiated on the characterization effort, and there was continued development of several three-dimensional air quality models.

Field data from the Pittsburgh Air Quality Study has improved understanding of several important phenomena regarding regional particulate matter. The summertime composition is dominated by organic carbon and sulfate, while wintertime composition is dominated by organic carbon, sulfate, and nitrate. Regional sources are the dominant contributor to particulate matter in the Pittsburgh region. Organic aerosol concentrations averaged approximately  $8 \text{ ug/m}^3$  during summer of 2001 and  $5 \text{ ug/m}^3$  during the winter of 2002. On average,  $30 \pm 20\%$  of the organic aerosol is secondary in summertime, while in winter the secondary organic aerosol is less than 20% of the total OC. Aerosols in summertime retained water even at low relative humidities ( $<30\%$ ), while in wintertime aerosols were typically dry at relative humidities below 50%; this behavior is consistent with acidic summertime aerosol and neutralized wintertime aerosol.

Planning of the source characterization effort continued this project period. Permission has been obtained to sample in a highway tunnel, a coal-boiler, and fence line sites next to a steel mill and coke production facility. The source sampling effort will begin next project period.

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## INTRODUCTION

This is the third semi-annual report of the “Pittsburgh Air Quality Project” (PAQS) funded by the U.S. Department of Energy’s National Energy Technology Laboratory under DOE Cooperative Agreement No. DE-FC26-01NT41017 to Carnegie Mellon University. This work is also supported by the US EPA through the Supersites program. In this three-year project, Carnegie Mellon University will conduct detailed studies of the ambient particulate matter in the Pittsburgh, PA metropolitan area. The work includes ambient monitoring, source characterization, and modeling (statistical and deterministic) for source apportionment. The major objectives of the project include:

- To achieve advanced characterization of the PM in the Pittsburgh region. Measurements include the PM size, surface, volume, and mass distribution; chemical composition as a function of size and on a single particle basis; temporal and spatial variability.
- To obtain accurate current fingerprints of the major primary PM sources in the Pittsburgh region using traditional filter-based sampling and state-of-the-art techniques such as dilution sampling and single particle analysis using mass spectroscopy and LIBS.
- To estimate the impact of the various sources (transportation, power plants, natural, etc.) on the PM concentrations in the area using both statistical and deterministic models.
- To quantify the responses of the PM characteristics to changes in these emissions in support of the emission control decision making in the area.
- To develop and evaluate current and next generation aerosol monitoring techniques for both regulatory applications and for determination of source-receptor relationships.

## EXPERIMENTAL

This section provides an overview of the effort on various project activities. This project period the majority of the effort went into activity 2 ambient monitoring; more limited effort was spent planning the upcoming source characterization effort and in the continued development of three-dimensional air quality models.

### Activity 1. Project Management

During this project period conference calls were used to review data from the ambient sampling and to coordinate future work. The PAQS data management team has been working to submit data to the NARSTO archive, and Clarkson University for incorporation in the EPA sponsored relational database. The NARSTO format of approximately 80% of July 01 intensive data has been checked by the NARSTO Quality Systems Science Center; several data sets have been checked as many as three times. We are continuing to work on debugging the format. The goal is to have a large fraction of

the July 01 through September 01 data submitted to the NARSTO archive by the end of September 02. We have initiated transfer of data to Clarkson University for inclusion in EPA sponsored the relational database.

## **Activity 2. Ambient Monitoring**

The purpose of this activity is to create an extensive database of ambient PM measurements for source apportionment, examination of aerosol processes, evaluation of instrumentation, and air quality model development and evaluation. Ambient measurements were conducted throughout this project period on the baseline schedule. On July 31, 2002 a large number of manual measurements were stopped. Limited baseline measurements are scheduled to continue through Sept 30, 2002. Table A.1 summarizes the list of measurements and sampling frequency during this project period.

During this project period, speciation measurements were made by the PA Department of Environmental Protection at Florence, PA and Greensburg, PA and by the Allegheny County Health Department at Lawrenceville and Hazelwood neighborhoods of Pittsburgh. These measurements were made on either a 1 in 3 or 1 in 6 day schedule as part of the EPA speciation network. The Athens, OH satellite site was operated during this project period by Ohio University. Samples at this site were collected on a 1 in 6 day schedule in coordination with the EPA speciation network.

Two special experiments using satellite sites were conducted during the project period. First, an SMPS system was installed and operated for 2 months at the Florence site to examine the regional nature of the nucleation events described in the September 2001 through January 2002 progress report. Second, samples for organic speciation were collected at the Florence site to look at the regional characteristics of organic PM.

### ***Single Particle Mass Spectrometry:***

The University of California at Davis and University of Delaware operated a rapid single particle mass spectrometer (RSMS) at the main supersite. The RSMS is an art-of-the-state instrument capable of analyzing and sizing individual particles over the size range from 20 nm to 2  $\mu$ m. The instrument is operated remotely by the UC Davis and the University of Delaware team with occasional hands-on maintenance. Considering the complexity of the instrument, the instrument has been extremely reliable and the experiment in Pittsburgh is surprisingly successful. This is the first time that anyone has ever operated a single particle instrument continuously for this length of time and done so remotely.

Measurements were initiated in September 2001 and data have been collected on over 260 days. We record up to 30 spectra for each of 9 particle sizes and thus record the composition of up to 270 particles for each scan. The initial schedule of the measurement started at 1:00 AM each day on a three-hour cycle and the time spent on each orifice is limited to 10 minutes. The three-hour cycle means that 8 scans are run per day for a total of up to 2160 particles per day. In order to increase temporal coverage, the schedule has

been changed to start at 00:00 AM each day on a two-hour cycle and the time spent on each orifice be limited to 5 minutes. The two-hour cycle increases the number of scans from 8 to 12 per day. In total, up to 3240 particles may be recorded per day. We have been averaging about 2000 particle hits per day for both schedules.

The RSMS instrument had a major overhaul in May 2002. After that, the background level of the instrument has decreased significantly, enabling us to record more weak peaks of the particles. The RSMS instrument also had several minor modifications during hand-on maintenance to (1) enhance the performance at smaller particle sizes, (2) reduce the risk of instrument damage in case that power fails, and (3) stabilize the laser beam to source region.

The fail-safe devices installed in January 2002 have been successful in preventing damage to the instrument during unexpected events. For example, there was a power failure for more than 40 hours in June 2002 due to a sever storm, but the RSMS instrument's self protection devices shutdown the instrument without damage. In July 2002, one of three vacuum pumps broke down, but again, the pressure-fail self protection features saved the instrument from damage.

A new method has been developed to obtain particle concentrations from RSMS data. The particle concentration of a given particle type measured with RSMS is given by:

$$\left[ dN / d(\log d_p) \right]_{RSMS} = \frac{N / tV}{D \log \left( \frac{d_m}{\sigma_g} \right)^2}$$

where N is the total number of particles detected during measurement time interval  $t$ , V is the volume flow rate of aerosol into the mass spectrometer, D is the detection efficiency of the mass spectrometer (fraction of particles entering the inlet that are detected and analyzed),  $d_m$  is the median diameter transmitted by the inlet,  $\sigma_g$  is the geometric standard deviation of the inlet transmission function, and  $\log (d_m/\sigma_g)^2$  represents the width of the transmission function between 16% and 84% of the size distribution. During this project period, the Delaware group has measured D and  $d_m/\sigma_g$  for the RSMS configuration. These parameters allow  $dN/d(\log d_p)$  to be determined from the above equation for particles containing specific chemical components. This capability should facilitate source apportionment and exposure studies with RSMS data.

### ***Characterization of Organic Aerosol***

Rutgers University has completed over one year of ambient sampling and some source sampling with a semi-continuous automated carbon analyzer at the Pittsburgh Air Quality Study. They are in the process of conducting final quality control on the entire data set. As discussed below, there is evidence that both local photochemistry and regional transport contribute to the organic particulate matter concentrations measured at Pittsburgh, similar to previous observations in Atlanta. Observations from the entire year

of data will be presented at the American Association for Aerosol Research annual meeting in Charlotte, NC in October.

In addition, over one year of high volume filter samples have been collected and the analysis method for quantifying organic carbon concentrations by polarity has been finalized. Extraction and analysis will begin this fall.

Size-resolved samples were collected during the summer and winter intensives and analyzed for functional groups by polarity. We observed days where carbonyl concentrations peaked in the condensation mode and other days where both condensation and droplet modes were observed. Organosulfur compounds are sometimes present, as we have previously observed in the Smoky Mountains. These compounds could be formed through the cloud processing of aldehydes in the presence of acidic sulfate.

### **Activity 3. Source Characterization**

#### ***Activity 3.1 Emissions and Activity Survey***

Work continued compiling emission inventory information for the modeling effort.

#### ***Activity 3.2 Source Sampling***

During this reporting period preparations were continued for the source sampling effort. Table A.2 summarizes the planned set of measurements.

During this project period, we obtained formal permission to sample in the Squirrel Hill Tunnel (a tunnel on Interstate 376 located ~ 2 miles from the central monitoring site), the Bellefield Boiler (a coal-fired steam generator located ~ 0.5 miles from the central monitoring site), and at the Allegheny County Department of Health North Braddock and Lincoln monitoring sites. The Lincoln site is adjacent to the largest coke production facility in the United States; the North Braddock site is next to a large steel mill. The plan is to conduct fence line monitoring at these sites with high time resolved continuous instruments to determine fingerprints for these source categories. We are still working on arranging permission to sample at a full-scale coal boiler.

Several feasibility studies were performed this project period to prepare for the source sampling effort. Preliminary data suggest that source sampling in the Squirrel Hill tunnel is feasible. Data were also obtained from the Allegheny County Health Department to evaluate feasibility of the Lincoln and N. Braddock fence line sites. These data suggest that the Lincoln site is heavily impacted by the coke facility and that there should be plenty of signal to use fence line measurements to determine a fingerprint for the facility; it is not clear if the impact of the near by steel mill on the N. Braddock site is significant enough to justify fence line monitoring. We plan to set up a small suite of instrumentation to further evaluate the feasibility of the N. Braddock site.

Collection of road dust was initiated during this project period. A road dust sample is being collected from an urban road and a rural road. The collected material will be suspended in a Teflon bag; a PM<sub>2.5</sub> sample will then be collected from the suspended material for determination of the road dust fingerprint for urban and rural road dust.

Work is underway to categorize the dominant flora and fauna in Southwestern Pennsylvania. Based on the results of this survey, a representative sample of vegetation will be collected and then suspended in a Teflon bag. PM<sub>2.5</sub> samples will then be collected and analyzed to determine a fingerprint for the vegetation.

Sampling is scheduled to start for the coke facility on August 15, 2002. We will then characterize the steel facility, tunnel, and coal boiler. We hope to complete this effort during the upcoming project period.

#### **Activity 4. Source Apportionment**

The Hopke group at Clarkson University has begun work on source apportionment. The positive matrix factorization (PMF) method has been applied to the analysis of the particle size distribution data acquired during the Pittsburgh Air Quality Study (PAQS) from July 2001 to August 2001. After removing those days with nucleation events, a total of 1632 samples each with 165 size intervals from 0.003 to 2.5  $\mu\text{m}$  were obtained from Scanning Mobility Particle Spectrometer (SMPS) and Aerodynamic Particle Sampler (APS). The temporal resolution is 15 minutes. The data of every five consecutive size bins were summed to produce 33 new size channels. The size distributions of particle number as well as volume were analyzed with a bilinear model, where  $x_{ij}$  is the number or volume of particles in  $j$ th size interval for the  $i$ th sample,  $f_{kj}$  is the size distribution associated with  $k$ th source,  $g_k$  is the number or volume of particles from the  $k$ th source associated with the  $i$ th sample, and  $e_{ij}$  is the residual in the fit.

Three kinds of information were used to identify the sources: the number and volume size distributions associated with the factors, the time series properties of the contribution of each source (Fourier transformation of  $G$  factors) and the correlations of the  $G$  factors with the gas phase data. By these analyses, the sources were found to be secondary aerosol, remote traffic, close traffic, vegetation burning, and local food preparation services. A conditional probability function (CPF) for each source was calculated to identify the likely directions of the sources relative to the receptor site.

#### **Activity 5. Three-Dimensional Deterministic Modeling**

During this reporting period the CMU modeling team has continued the development of the aerosol modeling tools, incorporated them in 2 three-dimensional chemical transport models (URM and CAMx-AERO), and evaluated them against available data sets. The Trajectory-Grid (T-G) approach has been incorporated in the CMU Hybrid Aerosol Module and the results have been compared to the currently used approach (Adams method in the LSODE package) in a one-dimensional Lagrangian trajectory

model. The performance of the T-G method was excellent, decreasing the CPU cost by an order of magnitude without sacrificing any accuracy. The CMU aerosol modules (Equilibrium, Dynamics-MADM, and Hybrid) have been added to CAMx and have been used to simulate a 1995 pollution episode in Southern California. The performance of the model was very good both in terms of accuracy and computational efficiency. We are currently setting up the models for simulations in the Eastern United States domain using meteorological and emissions fields from the NARSTO 1995 campaigns. After this testing we will focus on the simulations for the July 2001 intensive (ESP01).

## RESULTS AND DISCUSSION

The average PM<sub>2.5</sub> level measured for the first 7 months of the PAQS was 17 µg/m<sup>3</sup>, with higher levels during summer than winter. A summary of data is shown in Table 1. The summertime composition is dominated by organic carbon and sulfate, while wintertime composition is dominated by organic carbon, sulfate, and nitrate.

**TABLE 1. Summary of Average Measurements from the Pittsburgh Air Quality Study**

Parameter	Summer Intensive (July 2001)	Winter Intensive (January 2002)
PM <sub>2.5</sub> (µg/m <sup>3</sup> )	24	11
Temperature (°C)	22.8	3.0
Relative Humidity (%)	66	68
Average UV (W/m <sup>2</sup> )	7.8	2.0
PM <sub>2.5</sub> Sulfate (µg/m <sup>3</sup> )	7.6	3.6
PM <sub>2.5</sub> Nitrate (µg/m <sup>3</sup> )	0.5	2.2
PM <sub>2.5</sub> Organic Carbon (µg/m <sup>3</sup> )*	7.9	4.7
PM <sub>2.5</sub> Elemental Carbon (µg/m <sup>3</sup> )	0.8	0.4

Regional-scale meteorology had a strong influence on ambient mass concentrations. Highest concentration periods occurred during stagnant warm periods of high pressure and low wind speeds. Concentrations of sulfate, nitrate, and organic carbon showed minimal diurnal pattern on average, suggesting that concentrations of these components are dominated by regional transport and meteorology. Concentrations of elemental carbon showed somewhat more diurnal variation, suggesting significant local source contributions.

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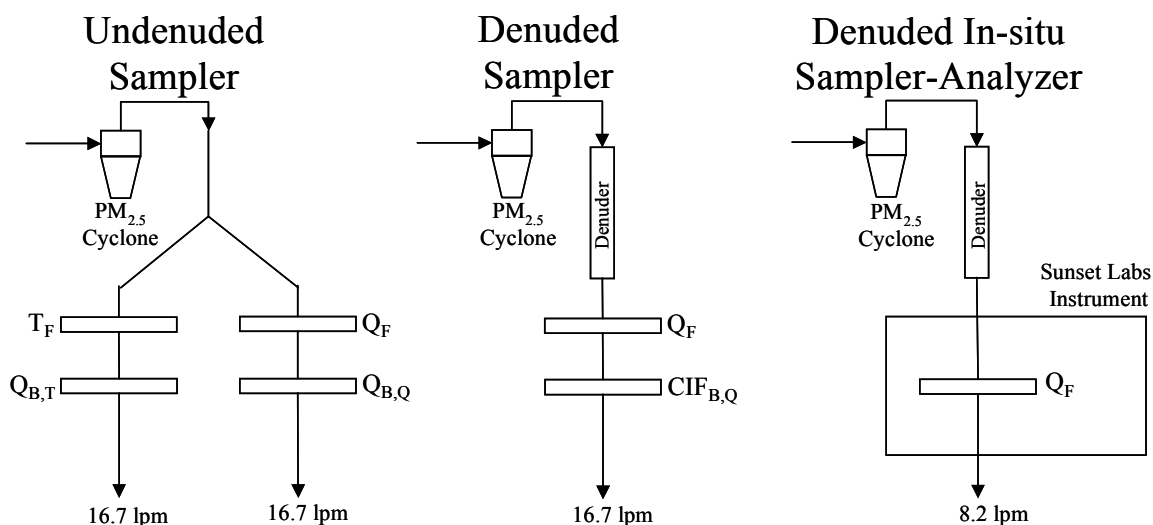
\* Undenuded quartz filter with multiplier of 1.8 µg OC / µg Carbon

## Secondary Organic Aerosol

A major component of  $PM_{2.5}$  in the Eastern US is carbonaceous material. Organic particulate matter results from both direct emissions from sources such as automobiles, trucks and industries (primary), and from the oxidation of organic gases (secondary). Data from the Pittsburgh Air Quality Study are used to examine the contribution of secondary organic aerosol to the total organic aerosol loading measured in the city during 2001 and 2002.

### *Organic Methods:*

The Pittsburgh Air Quality Study (PAQS) operated three different samplers, shown in Figure 1, for collecting carbonaceous aerosol (one undenuded line and two denuded samplers). During the summer intensive (July-August 2001), an undenuded line and the denuded in-situ analyzer operated at high resolution sampling times (2-6 hrs), and another denuded line collected daily samples. During the regular sampling schedule (August 2001- April 2002), daily samples were collected on the undenuded sampler and 2-4 hrs samples were collected on the denuded in-situ analyzer.

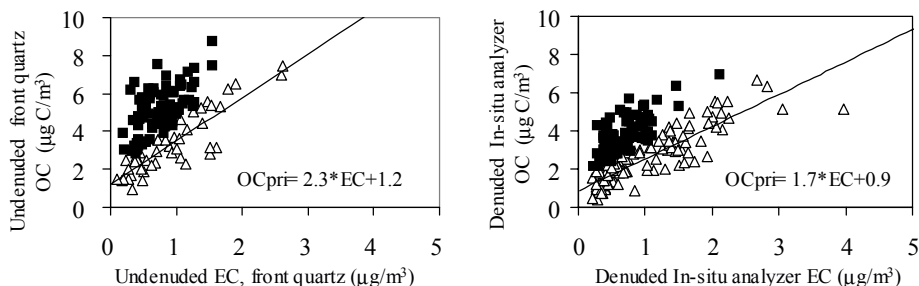


**Figure 1.** Schematic of the Pittsburgh Air Quality Study carbonaceous aerosol samplers. Subscript "F" denotes the front filter in the samplers. Backup filters are indicated as a subscript "B" followed by the type of filter they are after (T =Teflon, Q= quartz).

The contribution of secondary organic aerosol can be estimated by using elemental carbon as a tracer for primary emissions of organic particulate matter (OC to EC ratio approach). A systematic method for the determination of the primary ratio has been

developed based on the correlation of measurements of OC and EC to gaseous tracers of photochemical activity ( $O_3$ ) and primary emissions ( $CO$ ,  $NO_x$ ).

This method is applied to different sets of organic aerosols measurements for carbonaceous concentrations at PAQS. Carbonaceous concentrations are classified into primary and secondary organic aerosol influenced, depending on their correlation to the tracers. Figure 2 shows the classification of points for two datasets of measurements obtained during the summer intensive at PAQS.



**Figure 2.** Carbonaceous concentrations influenced by primary emissions (open triangles) and SOA production (black squares) for high-resolution measurements (2-6 hrs samples) during the July intensive at the PAQS.

A linear regression by least squares minimization is fitted through the “primary” emissions influenced concentrations. The slope of the fit represents the OC to EC primary ratio and the intercept represents the “non-combustion organic carbon” contribution to the primary OC concentration. Consistent results for the SOA fraction are obtained when the method is applied to sets of measurements with different sampling artifact corrections for OC and EC.

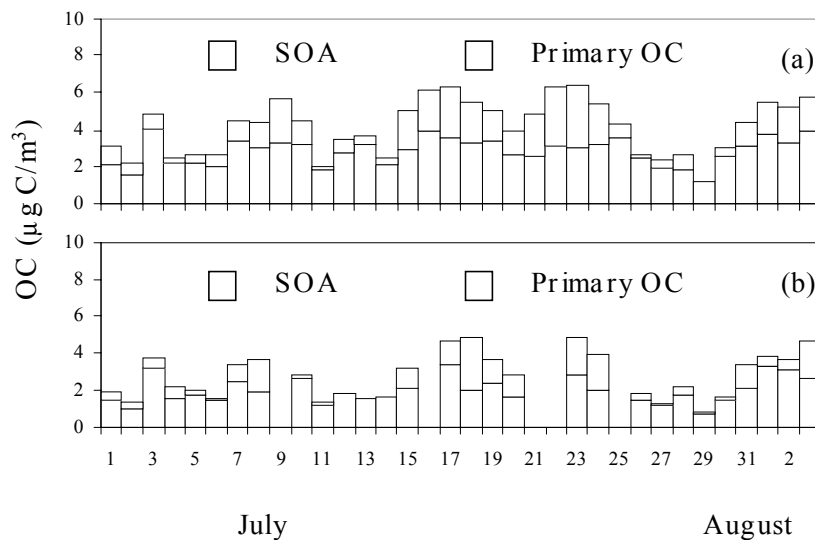
### ***Organic Results:***

Figure 3 shows daily resolved OC composition for two of the different samplers at PAQS, during the summer intensive (July-August 2001). Overall, the results based on the two datasets are in a good agreement, predicting the same periods of SOA production for July.

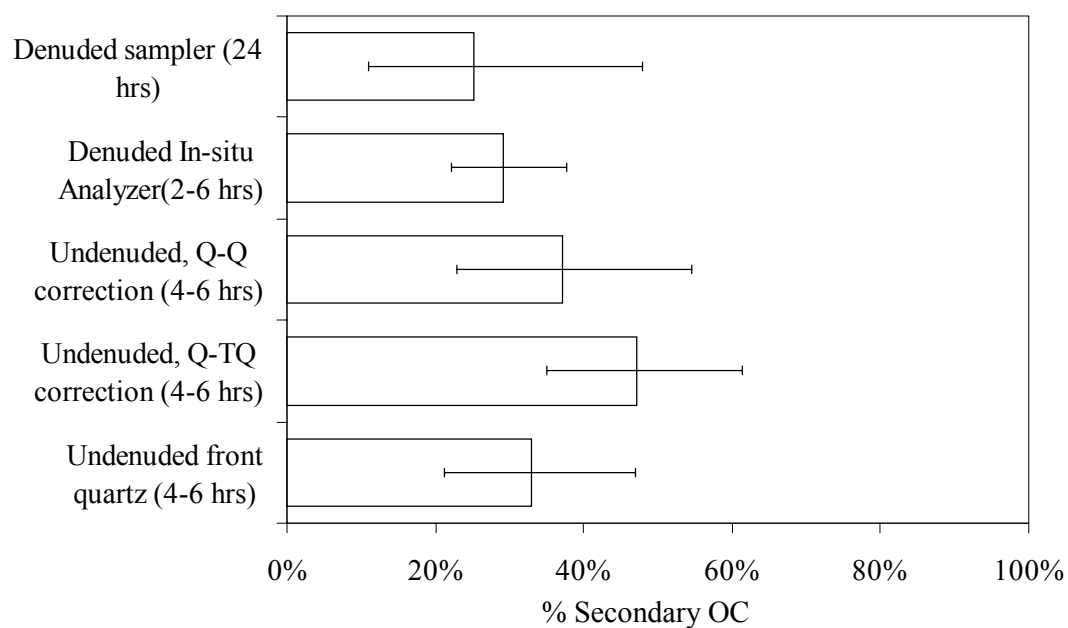
Monthly averaged OC compositions for all three different samplers are shown in Figure 4. Similar results in the OC composition are obtained for all of the different measurements taken, applying the same approach to determine the primary OC to EC ratio and intercepts. In average, for July 2001, 30% of the OC consisted of SOA.

Figure 5 shows the monthly averaged concentrations of OC and EC for Pittsburgh during 2001 and 2002. The approach to determine the SOA contribution is applied on a monthly basis and estimates of the primary ratio and the non-combustion OC contribution are calculated. Figure 6 shows the fraction of SOA from the total OC concentration measured. This approach indicates that between 20 and 30% of the organic particulate

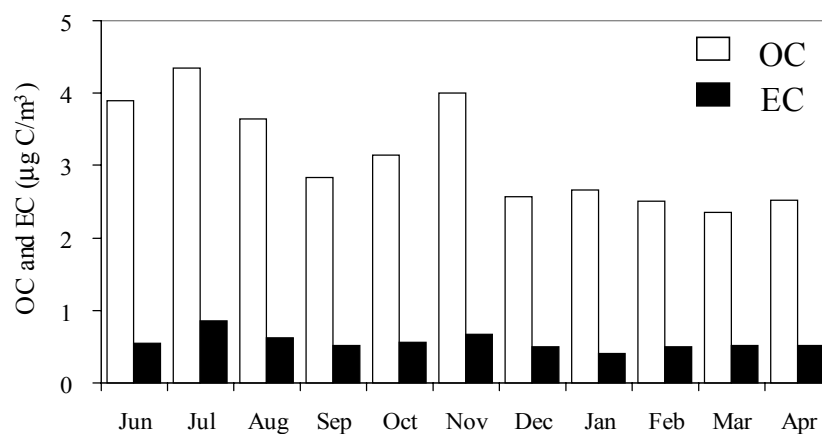
matter in Pittsburgh during the summer and fall of 2001 is secondary in origin while negligible contributions of SOA are estimated for the winter of 2001-02.



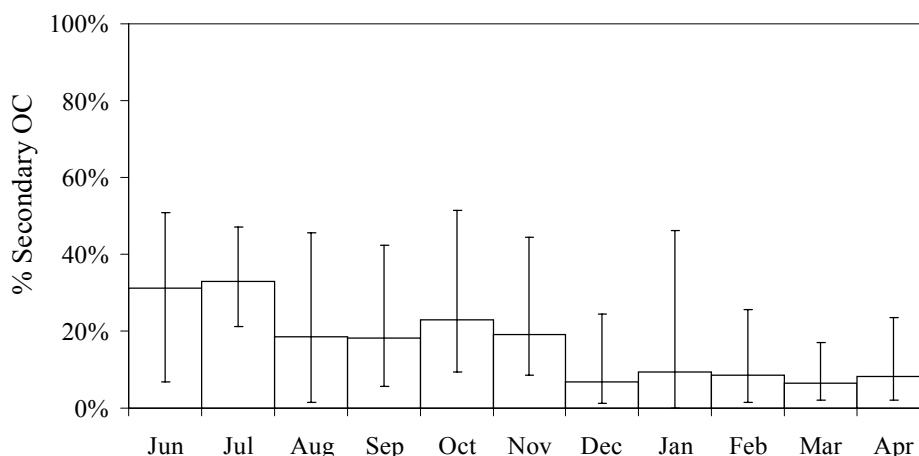
**Figure 3.** Daily averaged OC composition pattern during July, estimated from the high resolution measurements. SOA estimates were done with high-resolution parameters for the primary ratio and the non-combustion primary OC contribution. (a) Undenuded sampler using front quartz concentrations. (b) Concentrations from the denuded in-situ analyzer.



*Figure 4.* July monthly average SOA fraction of the Pittsburgh organic aerosol for all high-resolution datasets (2-6 hrs sampling times) and daily denuded sample (24 hrs). From all the datasets; in average 35 to 50% contribution of SOA is calculated for Pittsburgh in July 2001.



**Figure 5.** Monthly averaged carbonaceous aerosol concentrations for PAQS. Undenuded sampler, front quartz data.



**Figure 6.** Monthly fraction contribution of SOA to the total OC concentration for PAQS. Undenuded sampler, front quartz data.

### Water uptake by ambient aerosol

The ability of atmospheric particles to absorb water affects their lifetime, their light scattering properties, and their interactions with semi-volatile compounds. The hygroscopic growth of aerosol particles exhibits a hysteresis effect, so ambient particles can be either dry or wet between their crystallization and deliquescence points (for ammonium sulfate 40% and 80% RH, respectively). Due to the hysteresis effect the physical state of particles in the troposphere is uncertain, leading to uncertainties in their optical and chemical properties. Aerosol size distributions, dried and at ambient RH conditions, are being monitored within the Pittsburgh Air Quality Study (PAQS). Here we report our observations of aerosol water content at a wide range of relative humidities during a period of several months.

### ***Measurement of Aerosol Water Uptake***

An automated in-situ system was built to measure ambient aerosol size distributions at ambient and dry conditions. The system, called the Dry and Ambient Aerosol Size Spectrometer (DAASS) consists of two Scanning Mobility Particle Sizers (SMPS, TSI Inc.) and an Aerodynamic Particle Sizer (APS, TSI Inc.). The three instruments measure the aerosol size distribution between 5 nm and 10  $\mu\text{m}$  in diameter. The inlets of the instruments and the sheath air lines of the SMPS systems are equipped with computer controlled valves that direct air through Nafion dryers (PermaPure Inc.) or bypass them. The Nafion dryers are drying the air stream to below 40% RH at which point ambient particles are expected to lose most or all water and thus be virtually dry. The system is placed outside in a well-ventilated enclosure and is kept at ambient temperature to avoid changes in relative humidity and evaporation of volatile particles due to temperature differences. The switch between “dry” and the ambient conditions occurs every 6 minutes and is synchronized with the scan times of the aerosol spectrometers. In this way the system measures alternatively dry (below 40% RH) and wet (actual ambient RH) aerosol size distributions. Figure 7 shows the RH in the SMPS systems as it is varied between ambient and drying conditions. Figure 8 shows examples of wet and dry size distributions that are shifted due to hygroscopic growth.

A comparison of the “wet” and “dry” size distributions and the corresponding integrated volume concentrations provides a measure of the physical state of particles and the amount of aerosol water. These observations are compared with the GFEMN thermodynamic model predictions based on the simultaneously measured chemical composition data. Implications of water uptake are evaluated by comparing the DAASS measurements with the simultaneous the TEOM (R&P Co.) and the FRM (R&P Co.)  $\text{PM}_{2.5}$  mass measurements.

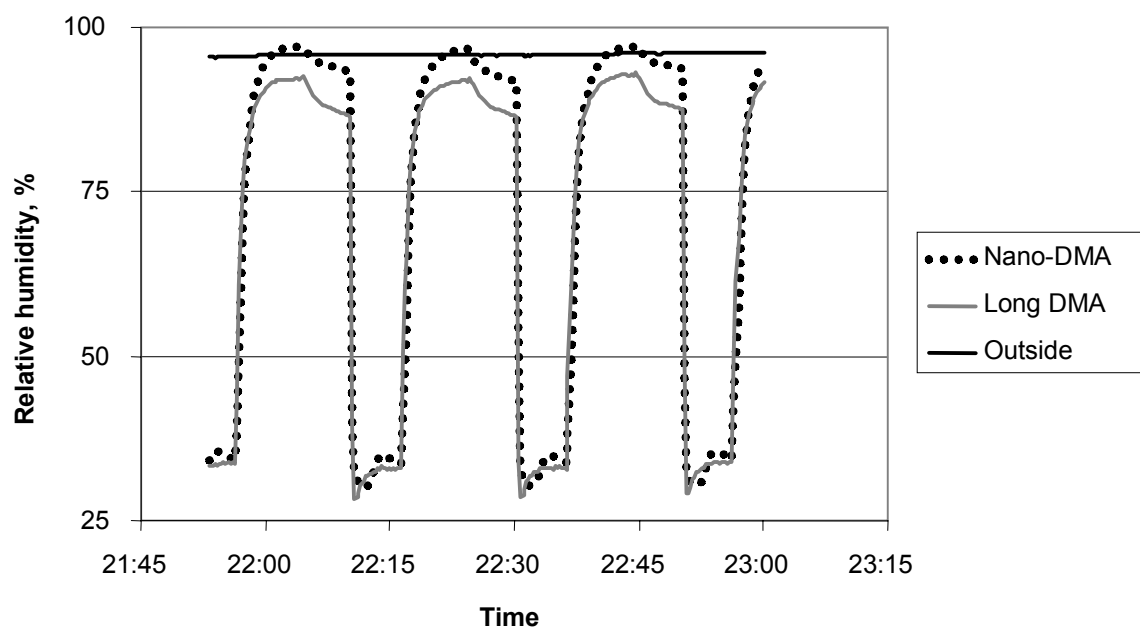


Figure 7. Cycling of relative humidities in Dry-Ambient Aerosol Size Spectrometer (DAASS).

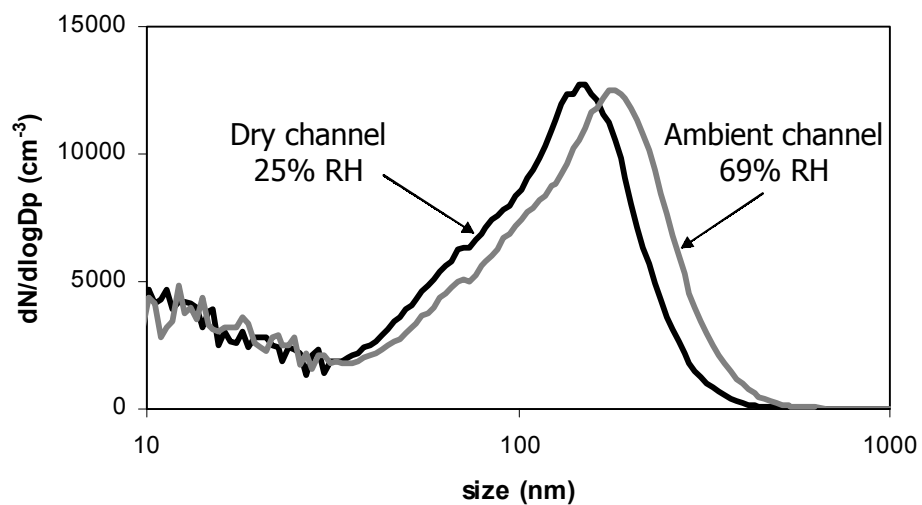
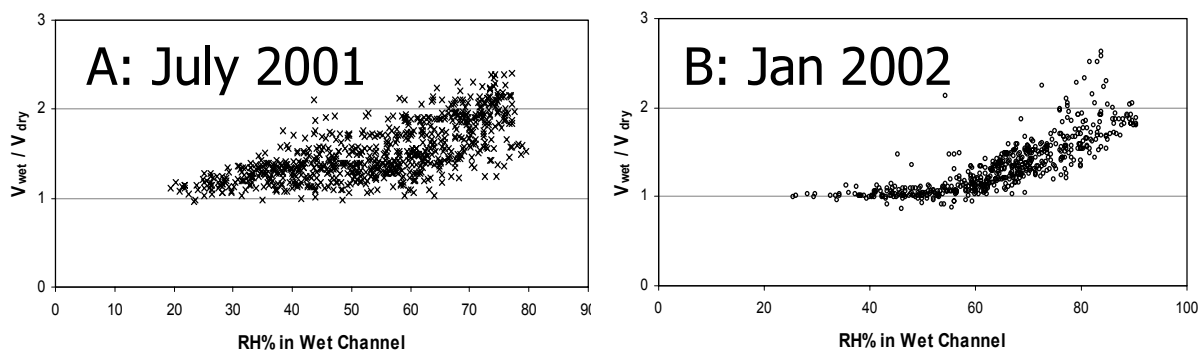


Figure 8. Example of difference between dried and ambient size distributions measured by DAASS.

### ***Results for Aerosol Water Uptake***

A comparison of “dry” and “wet” size distributions revealed that during the summer and autumn the ambient aerosol in Pittsburgh always contained water, even at RH as low as 30% (Fig. 9A). During the winter period, however, several periods were observed when particles were dry up to 65% RH (Fig. 9B). This behavior is consistent with the chemical composition of the aerosol and our understanding of its hygroscopic properties. During the summer particles in the area are often acidic. The dominant component, ammonium bisulfate does not crystallize down to about 10% RH. During the winter months the inorganic aerosol in Pittsburgh is dominated by ammonium sulfate and ammonium nitrate and thus crystallizes at higher RH.

The observed and GFEMN model-predicted growth factors are shown in Figure 10, which shows qualitative agreement for most periods, and reasonable quantitative agreement for many periods. These results indicate that the aerosol on some occasions may be composed of a mixture of crystallized and wet particles. The difference in the physical state may be the result of either different chemical composition (externally mixed aerosol) or different histories of the air parcels (particles may have experienced different RH).



**Figure 9.** Observed ratios of wet to dry aerosol volumes during July 2001 (A) and during January 2002 (B). Ratios above 1 indicate presence of water.

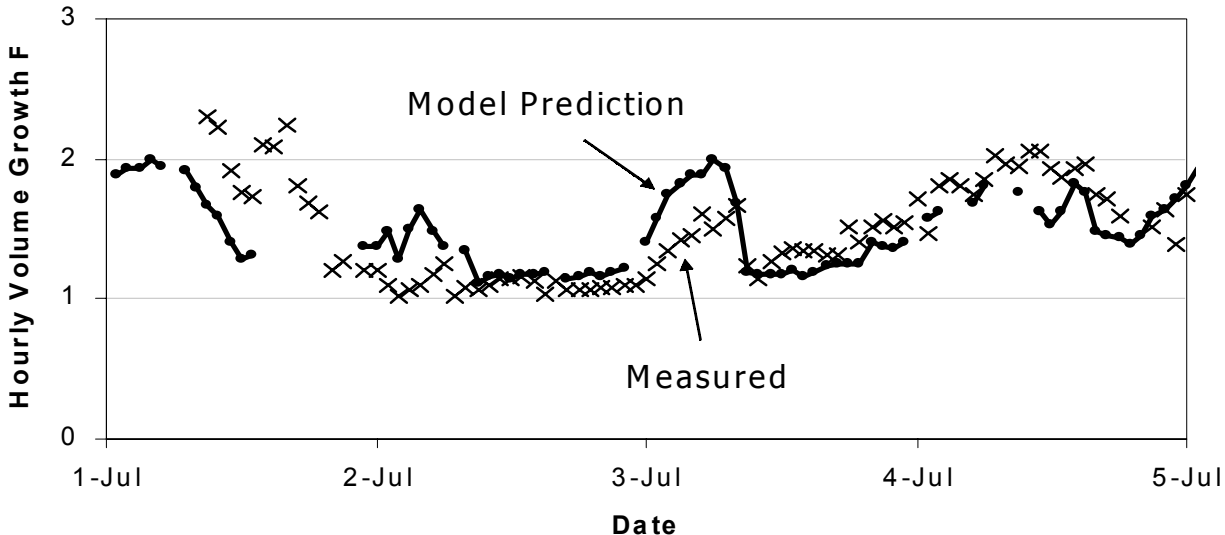


Figure 10. Model prediction of water uptake vs. measured data for selected period.

## CONCLUSIONS

Field data from the Pittsburgh Air Quality Study has improved understanding of several important phenomena regarding regional particulate matter. The summertime composition is dominated by organic carbon and sulfate, while wintertime composition is dominated by organic carbon, sulfate, and nitrate. Regional sources are the dominant contributor to particulate matter in the Pittsburgh region. Organic aerosol concentrations averaged approximately  $8 \text{ ug/m}^3$  during summer of 2001 and  $5 \text{ ug/m}^3$  during the winter of 2002. On average,  $30 \pm 20\%$  of the organic aerosol is secondary in summertime, while in winter the secondary organic aerosol is less than 20% of the total OC. Aerosols in summertime retained water even at low relative humidities ( $<30\%$ ), while in wintertime aerosols were typically dry at relative humidities below 50%; this behavior is consistent with acidic summertime aerosol and neutralized wintertime aerosol.

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## **PRESENTATIONS AND PUBLICATIONS**

### **Presentations**

S.L. Rees, S. Takahama, A.L. Robinson, A. Khlystov, and S.N. Pandis, "Seasonal Composition of PM<sub>2.5</sub> and Performance of the Federal Reference Method in Pittsburgh," PM<sub>2.5</sub> and Electric Power Generation: Recent Findings and Implications, National Energy Technology Laboratory, Pittsburgh, PA, April 10, 2002.

B. Wittig, A. Khlystov, S. Takahama, C. Davidson, A. Robinson, S. Hering, and S. Pandis, "Continuous Measurements of Ammonia, Sulfate and Nitrate in Pittsburgh: Implications for PM<sub>2.5</sub> Control Strategies," PM<sub>2.5</sub> and Electric Power Generation: Recent Findings and Implications, National Energy Technology Laboratory, Pittsburgh, PA, April 10, 2002.

J.C. Cabada-Amaya, R. Subramanian, S.N. Pandis, A.L. Robinson, W. Tang, N.J. Anderson, T. Raymond, and C.I. Davidson, "The Contribution of Long-Range Transport and Secondary Organic Aerosol to PM<sub>2.5</sub> in Pittsburgh," PM<sub>2.5</sub> and Electric Power Generation: Recent Findings and Implications, National Energy Technology Laboratory, Pittsburgh, PA, April 10, 2002.

G..S. Casuccio, S.F. Schlaegle, T.L. Lersch, R.P. Khoash, A.L. Robinson, P.J. Treado, and D.V. Martello, "Characterization of Ambient Particulate Matter Using Electron Microscopy and Raman Spectroscopy Techniques," PM<sub>2.5</sub> and Electric Power Generation: Recent Findings and Implications, National Energy Technology Laboratory, Pittsburgh, PA, April 10, 2002. (poster)

### **Publications**

J.C. Cabada, S.N. Pandis, and A.L. Robinson, "Sources of Atmospheric Carbonaceous Particulate Matter in Pittsburgh, Pennsylvania," *Journal of the Air & Waste Management Association*, **52**, 174-185, 2002.

**Table A.1. Measurements in the Pittsburgh Supersite Program for the Period of 8/1/01 – 1/31/02.**

Measurement	Instrumentation	Institution	Frequency Baseline	Frequency Intensives
<b>Filter-Based Composition</b>				
Wet and dry aerosol number distribution (3 nm – 10 µm)	Ultrafine SMPS: Scanning Mobility Particle Spectrometer (TSI model 3936N25) for 0.003-0.150 µm SMPS: Scanning Mobility Particle Spectrometer (TSI model 3934L) for 0.01-1.0 µm APS: Aerodynamic Particle Sizer Spectrometer (TSI model 3320) for 0.5-1.0 µm	Carnegie Mellon University	10 min	10 min
Aerosol surface area distribution	Epiphaniometer	Paul Scherrer Institute	10 min	10 min
<b>Mass measurements</b>				
PM <sub>2.5</sub> mass	R&P FRM	Carnegie Mellon University	1 day	1 day
PM <sub>2.5</sub> mass	Andersen DICHOT	Carnegie Mellon University	1 day	1 day
PM <sub>2.5</sub> mass	R&P TEOM (30°C + dryer)	Carnegie Mellon University	10 min	10 min
PM <sub>10</sub> mass	Andersen DICHOT	Carnegie Mellon University	1 day	1 day
PM <sub>x</sub> mass	MOUDI	Carnegie Mellon University	1 day	1 day
<b>Filter-Based Composition</b>				
PM <sub>2.5</sub> ions, PM <sub>2.5-10</sub> ions, HNO <sub>3</sub> vapor, NH <sub>3</sub> vapor	CMU Sampler + IC	Carnegie Mellon University	1 day	1 day
Size-resolved ions and metals	MOUDI + IC and ICP-MS	Carnegie Mellon University	-	1 day
PM <sub>2.5</sub> OC and EC	CMU TQQQ sampler	Carnegie Mellon University	1 day	1 day
PM <sub>2.5</sub> OC and EC	CMU denuder sampler	Carnegie Mellon University	1 in 6 days	1 day
PM <sub>2.5</sub> OC and EC, ions, and metals	PC-BOSS system	Brigham Young University	-	1 day
PM <sub>2.5</sub> OC and EC	Sunset Labs in situ carbon analyzer	Rutgers University	2 hr	2 hr
PM <sub>x</sub> OC and EC	MOUDI	Carnegie Mellon University	-	1 day
PM <sub>2.5</sub> Organic speciation	Filter & PUF + GC-MS Schenley Park Site	Florida International University & Carnegie Mellon University	1 in 6 days	1 day

Table 1 (cont.)

Measurement	Instrumentation	Institution	Frequency Baseline	Frequency Intensives
<b>Filter-Based Composition (cont.)</b>				
PM <sub>2.5</sub> Organic speciation	Filter & PUF + GC-MS Florence Satellite Site	Florida International University & Carnegie Mellon University	-	1 day
PM <sub>2.5</sub> metals	Hi-Vol + ICP-MS	Carnegie Mellon University	1 day	1 day
PM <sub>10</sub> metals	Hi-Vol + ICP-MS	Carnegie Mellon University	1 day	1 day
Organic size-resolved characterization	Hering Low pressure impactor + FTIR	Rutgers University	-	1 day
PM <sub>2.5</sub> Bio-aerosols	Epi-fluorescent microscopy, Molecular biology assays	University of Colorado at Boulder	1 day	1 day
<b>Single Particle Composition</b>				
Composition and size	Single Particle Mass Spectrometry: RSMS-III	University of California at Davis, University of Delaware	Continuous	Continuous
Elements and morphology	Filter + SEM	RJ Lee Group	-	1 day
Metals	Laser Induced Breakdown Spectroscopy (LIBS)	University of Maryland at College Park	-	-
<b>Semi-continuous composition</b>				
Semi-continuous metals	SEAS/GFAA	University of Maryland at College Park	-	-
PM <sub>2.5</sub> ions, HNO <sub>3</sub> vapor, NH <sub>3</sub> vapor	Steam Sampler + IC + FIA detector	Carnegie Mellon University	2 hr	2 hr
PM <sub>2.5</sub> nitrate	R&P 8400 Nitrate	Aerosol Dynamics & Carnegie Mellon University	10 min	10 min
PM <sub>2.5</sub> sulfate	R&P 8400 Sulfate	Aerosol Dynamics & Carnegie Mellon University	10 min	10 min
PM <sub>2.5</sub> carbon	Aerosol Dynamics Carbon Analyzer	Aerosol Dynamics	30 min	30 min
<b>Gases</b>				
VOCs	Cans & GC-FID, GC-MS	Carnegie Mellon University	1 in 3 days	1 day
in situ VOCs	GC-FID, GC-MS	University of California at Berkeley	-	1 hr
Total Peroxides	CSU Monitor	Colorado State University	30 min	10 min
Hydrogen Peroxide	CSU Monitor	Colorado State University	-	10 min

Table 1 (cont.)

Measurement	Instrumentation	Institution	Frequency Baseline	Frequency Intensives
<b>Gases (cont.)</b>				
Organic Peroxides	CSU Monitor	Colorado State University	-	10 min
Gases: O <sub>3</sub> , NO and NO <sub>x</sub> , SO <sub>2</sub> , CO	Gas Monitors	Carnegie Mellon University	10 min	10 min
<b>Other</b>				
Visibility	Nephelometer	Carnegie Mellon University	10 min	10 min
RH, T, P, Wind, UV and Solar Radiation	Met Station	Carnegie Mellon University	10 min	10 min
Fog and cloud composition	CSU sampler	Colorado State University	Variable	Variable

**Table A.2 Source Characterization Plan**

Source	Configuration	Instrumentation
Coke Facility	Fenceline.	<p>Continuous: Metals (Ondov), OC/EC (Turpin), size distribution (SMPS), PM2.5 mass (TEOM), gases (CO, NO<sub>x</sub>, SO<sub>2</sub>)</p> <p>Manual: Organic speciation, major ions, metals, size resolved organic function groups</p> <p>Other: Single Particle MS via Teflon Bag</p>
Steel Facility	Fenceline.	<p>Continuous: Metals (Ondov), OC/EC (Turpin), size distribution (SMPS), PM2.5 mass (TEOM), gases (CO, NO<sub>x</sub>, SO<sub>2</sub>)</p> <p>Manual: Organic speciation, major ions, metals</p> <p>Other: Single Particle MS via Teflon Bag</p>
Mobile Sources	Tunnel Exhaust Plenum	<p>Continuous: Metals (Ondov), OC/EC (Turpin), size distribution (SMPS), PM2.5 mass (TEOM), gases (CO, NO<sub>x</sub>, SO<sub>2</sub>, CO<sub>2</sub>)</p> <p>Manual: Organic speciation, major ions, metals</p> <p>Other: Single Particle MS via Teflon Bag</p>
Coal-fired steam boiler	Dilution sampling	<p>Manual: Mass, OC/EC, major ions, metals, organic speciation</p> <p>Other: Single Particle MS via Teflon Bag</p>
Vegetation	Suspend in bag	Organic Speciation
Road dust	Suspend in bag	OC/EC, major ions, metals, organic speciation
Wood smoke	Dilution sampling	OC/EC, major ions, metals, organic speciation